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(54) Optical element for use with an LED

(57) Optical element 38 allows light incident on the side of the LED encapsulent 10 to be redirected by total internal reflection via the optical element / air interface 38. This arrangement gives an increased light emission intensity. Alternatively the shape of the encapsulent material can be arranged to increase light emission intensity (Figure 5).

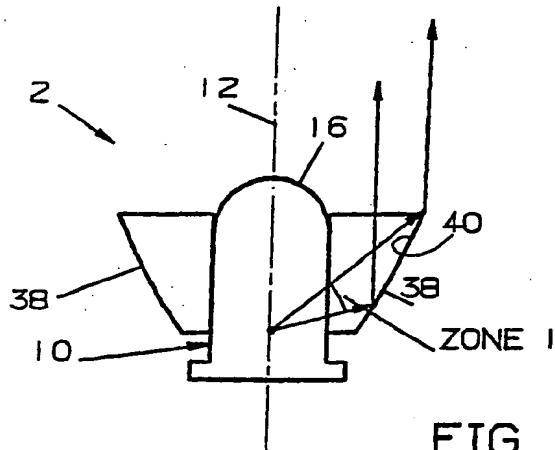


FIG 6

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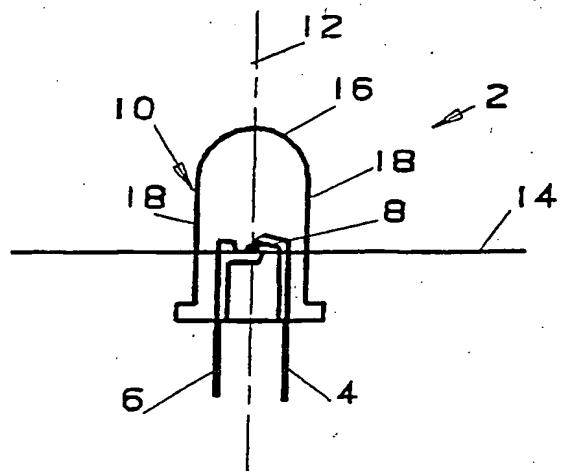


FIG 1

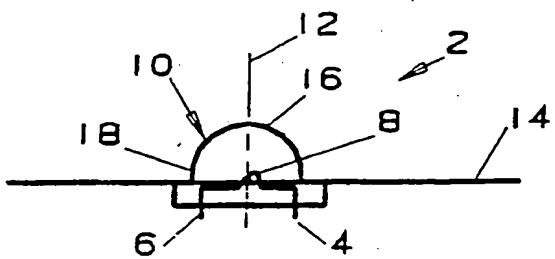


FIG 2

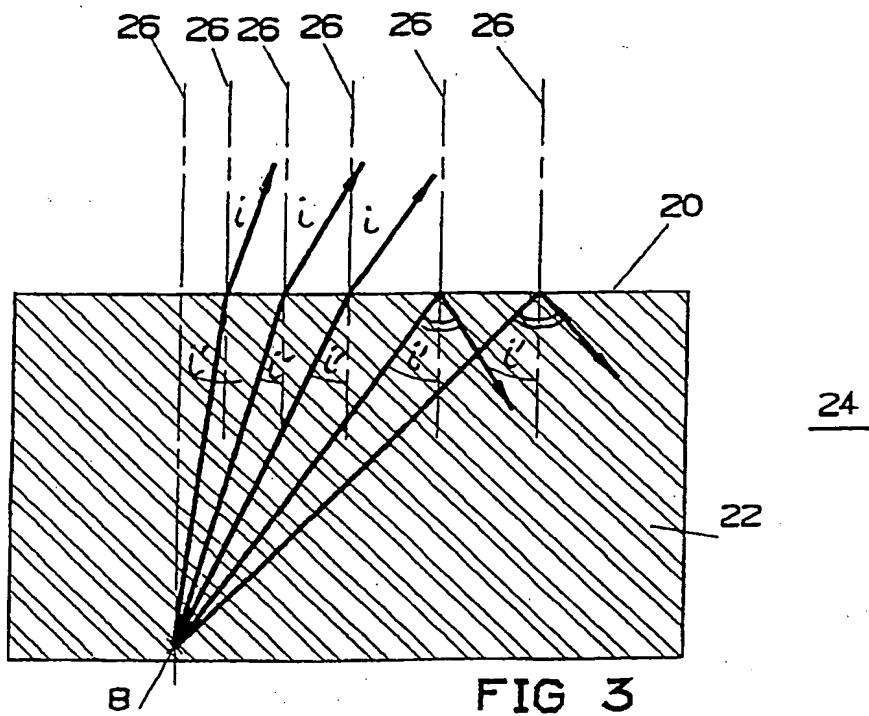


FIG 3

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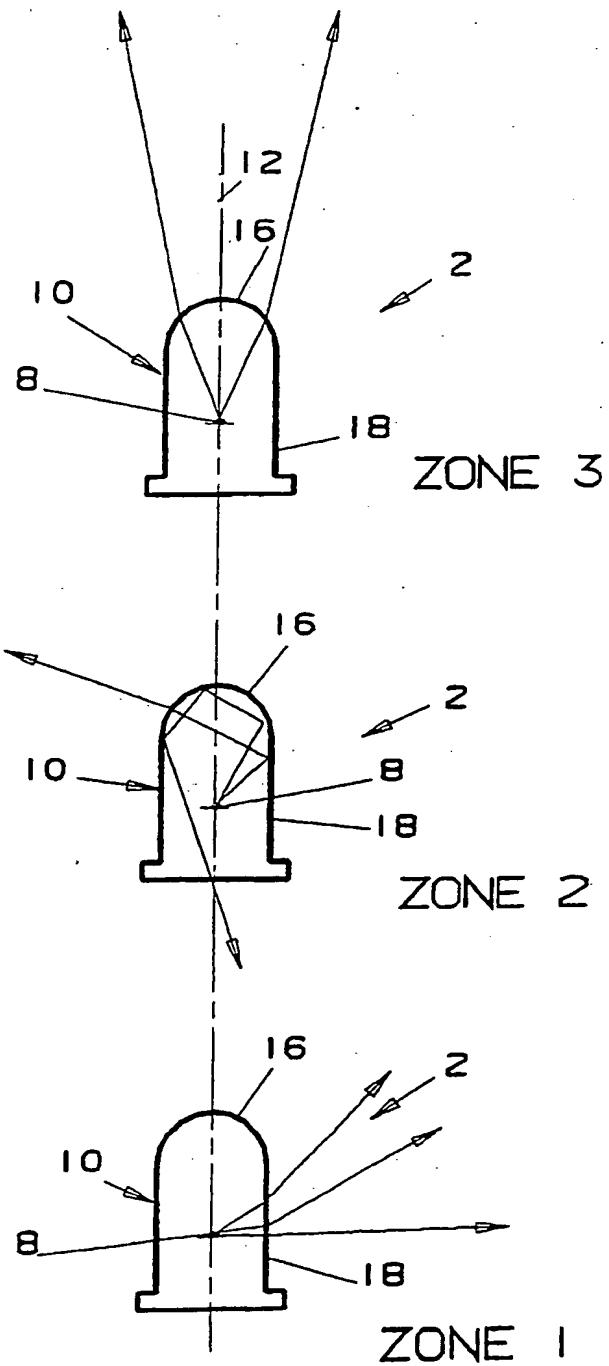


FIG 4

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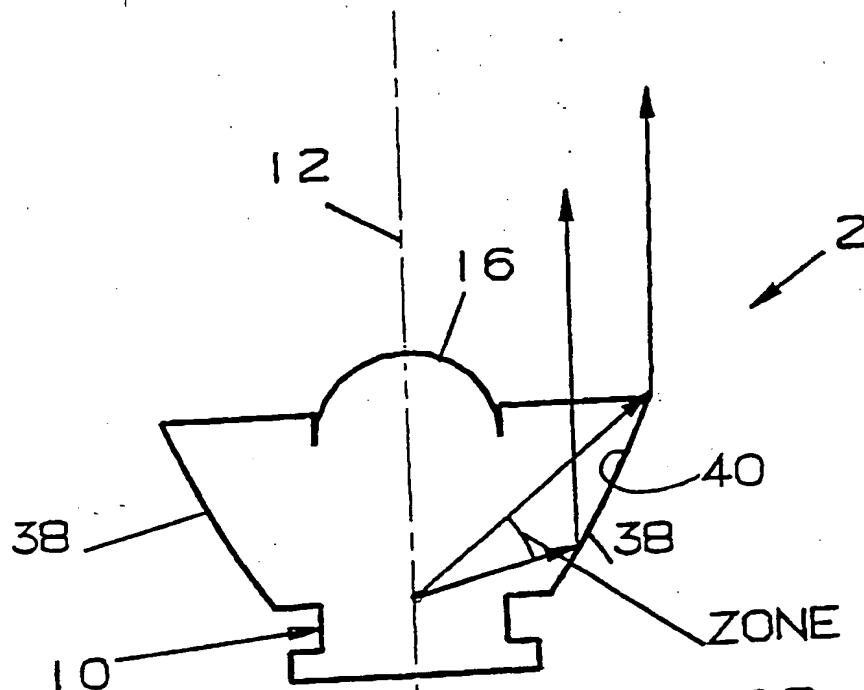


FIG 5

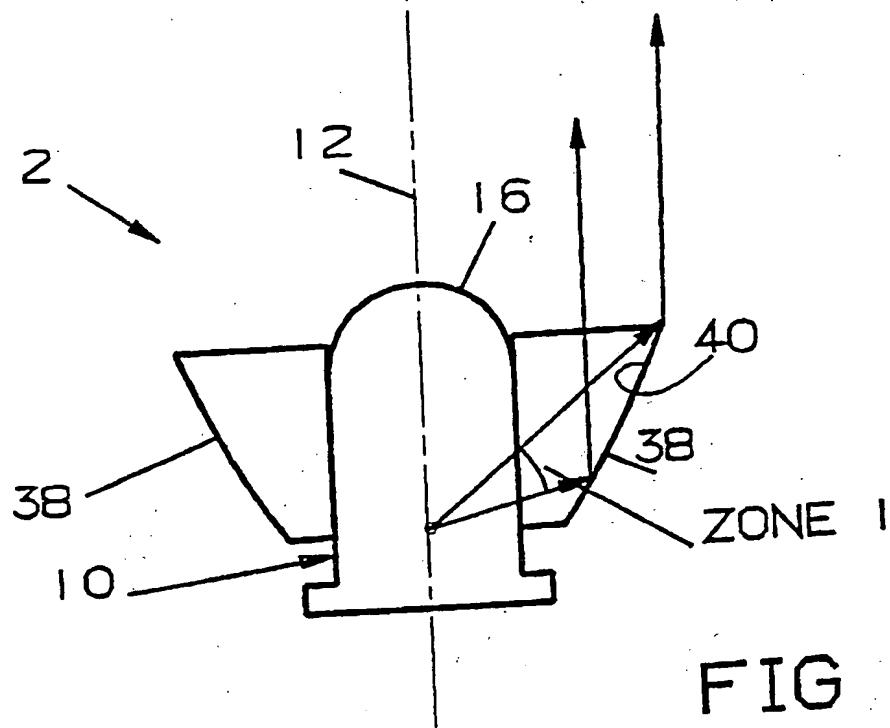


FIG 6

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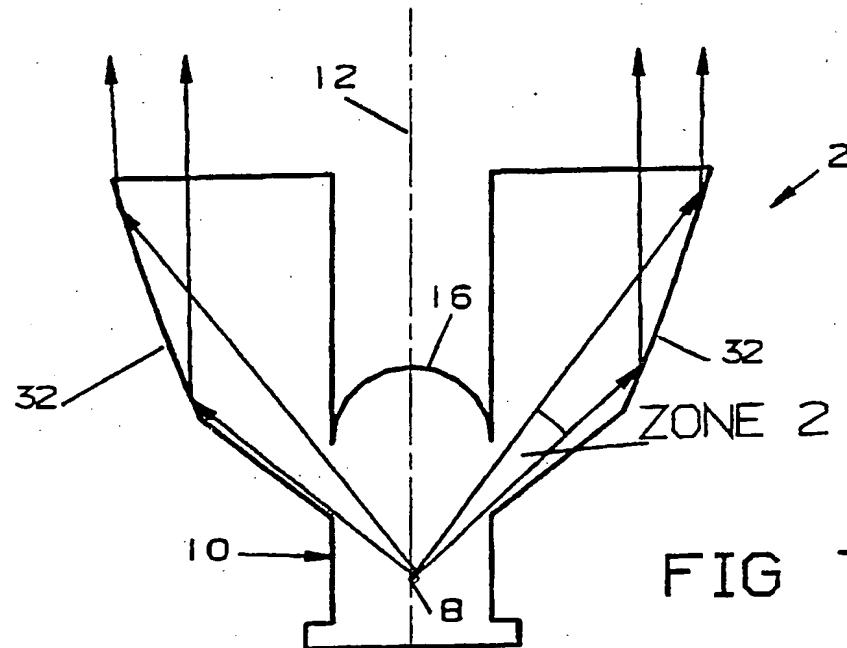


FIG 7

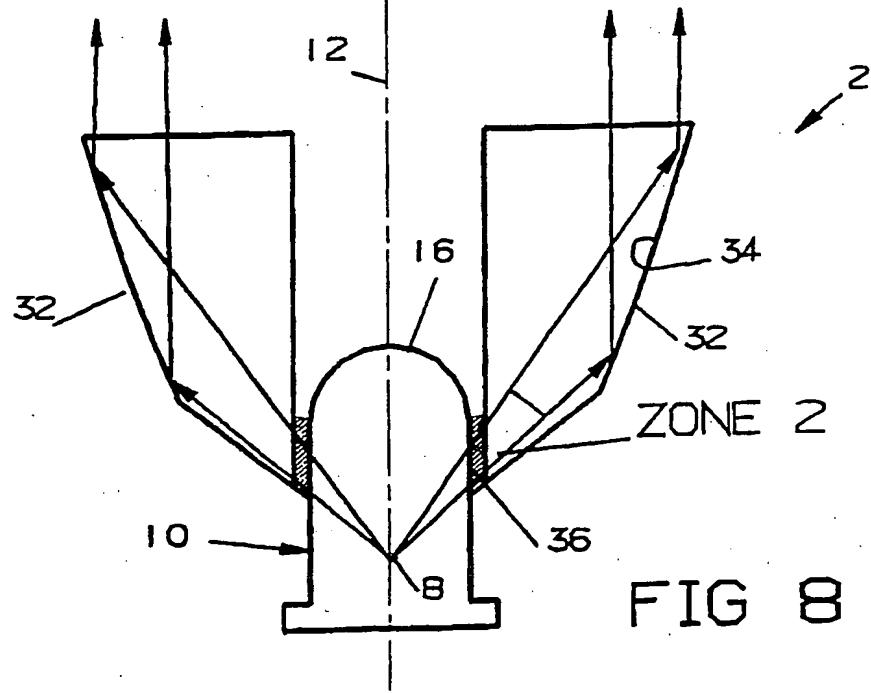


FIG 8

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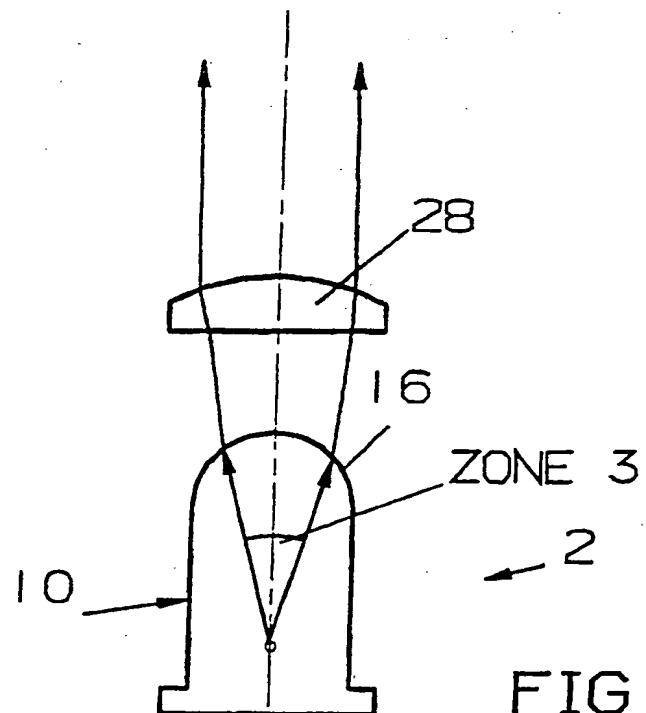


FIG 9

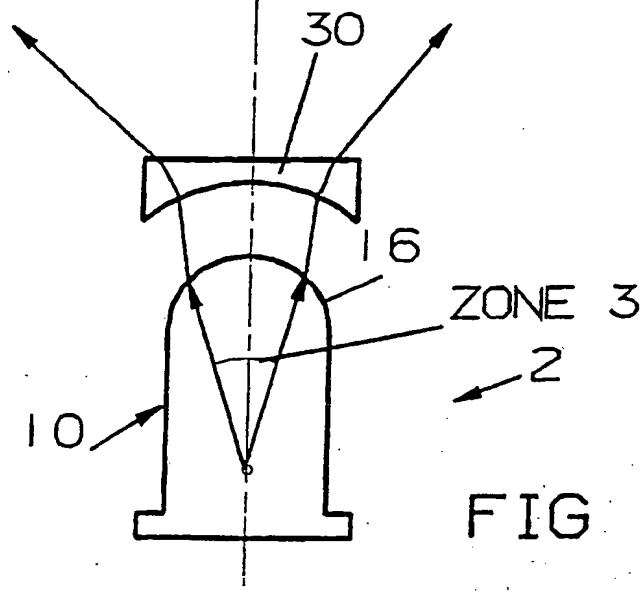
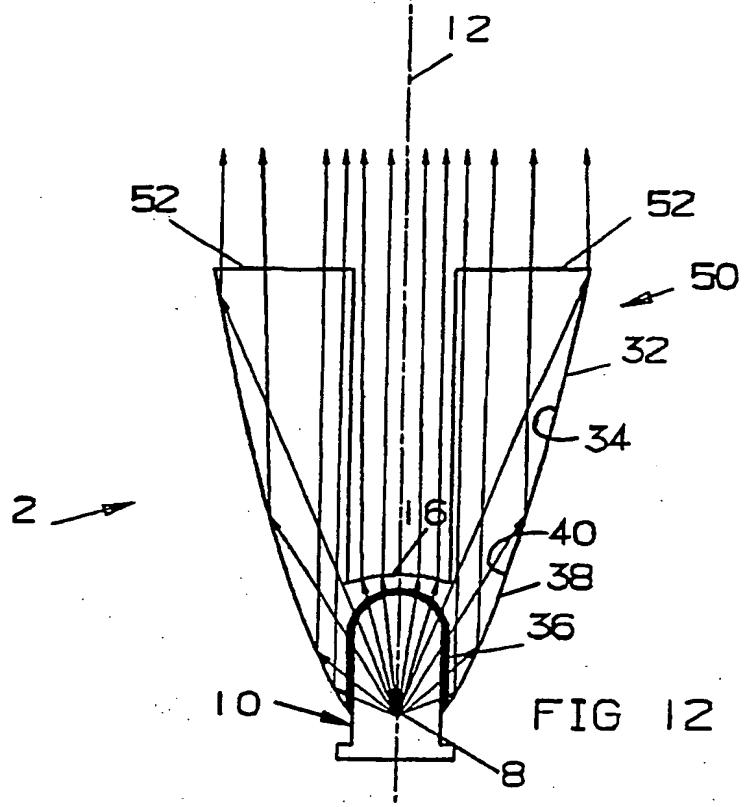
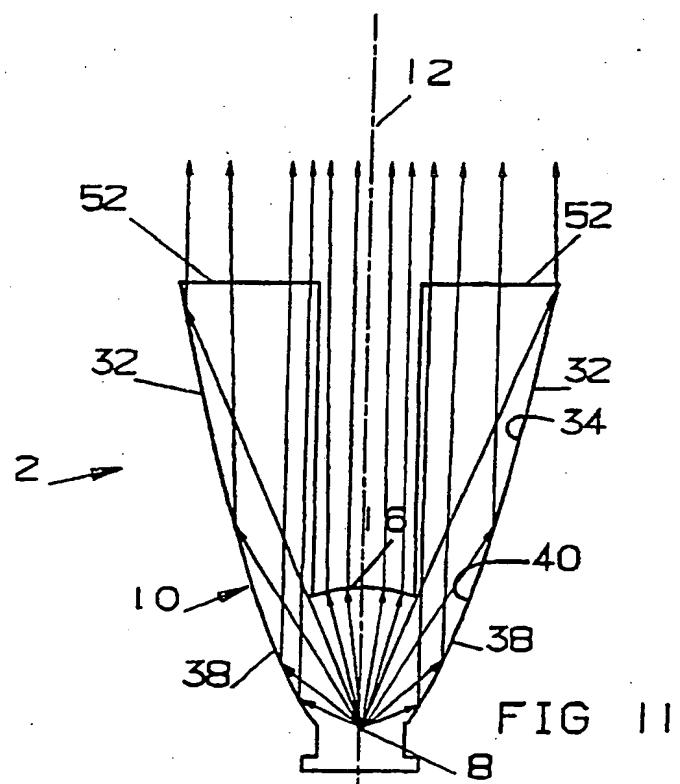


FIG. 10

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FIG 13

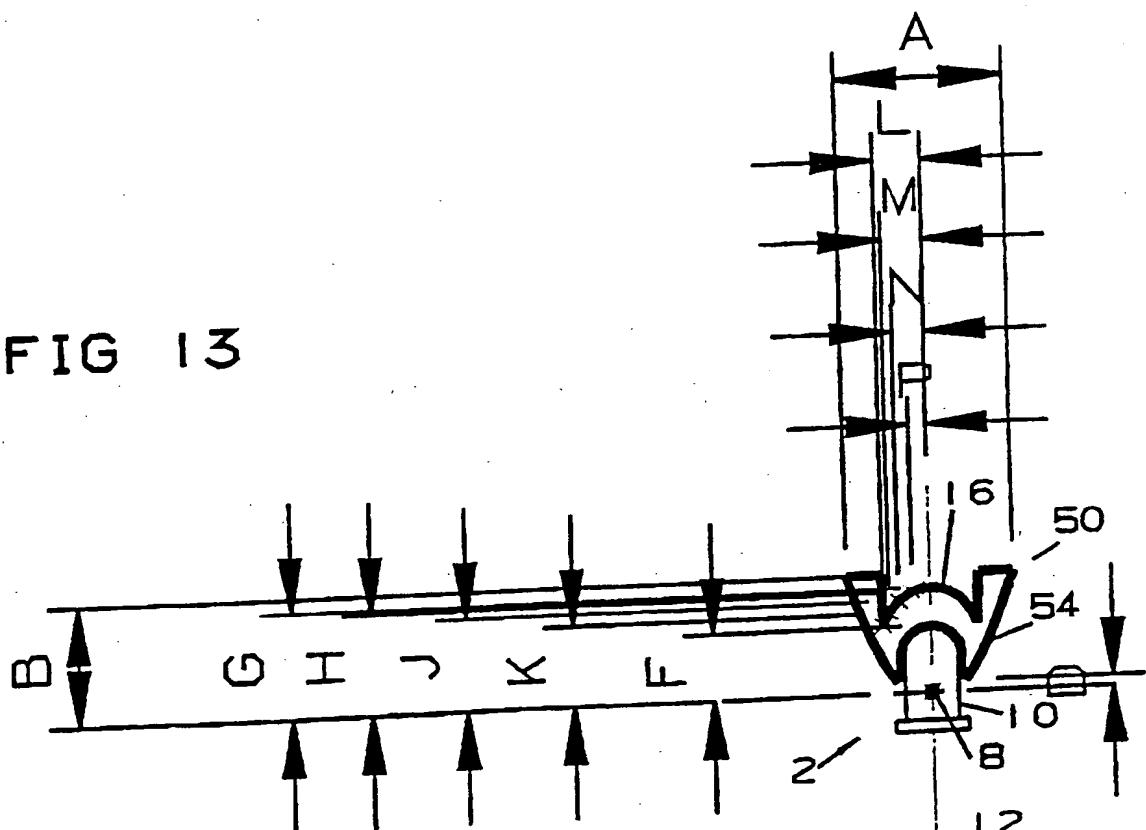
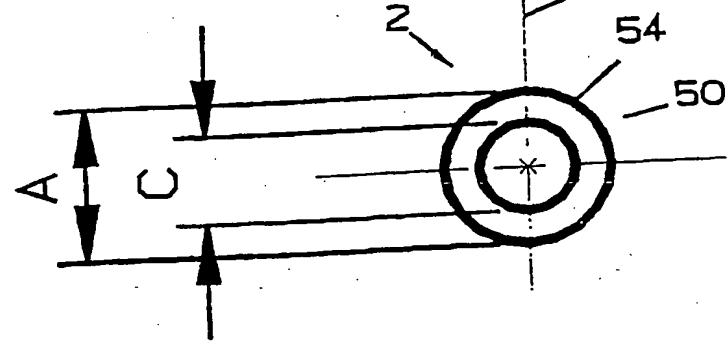


FIG 14



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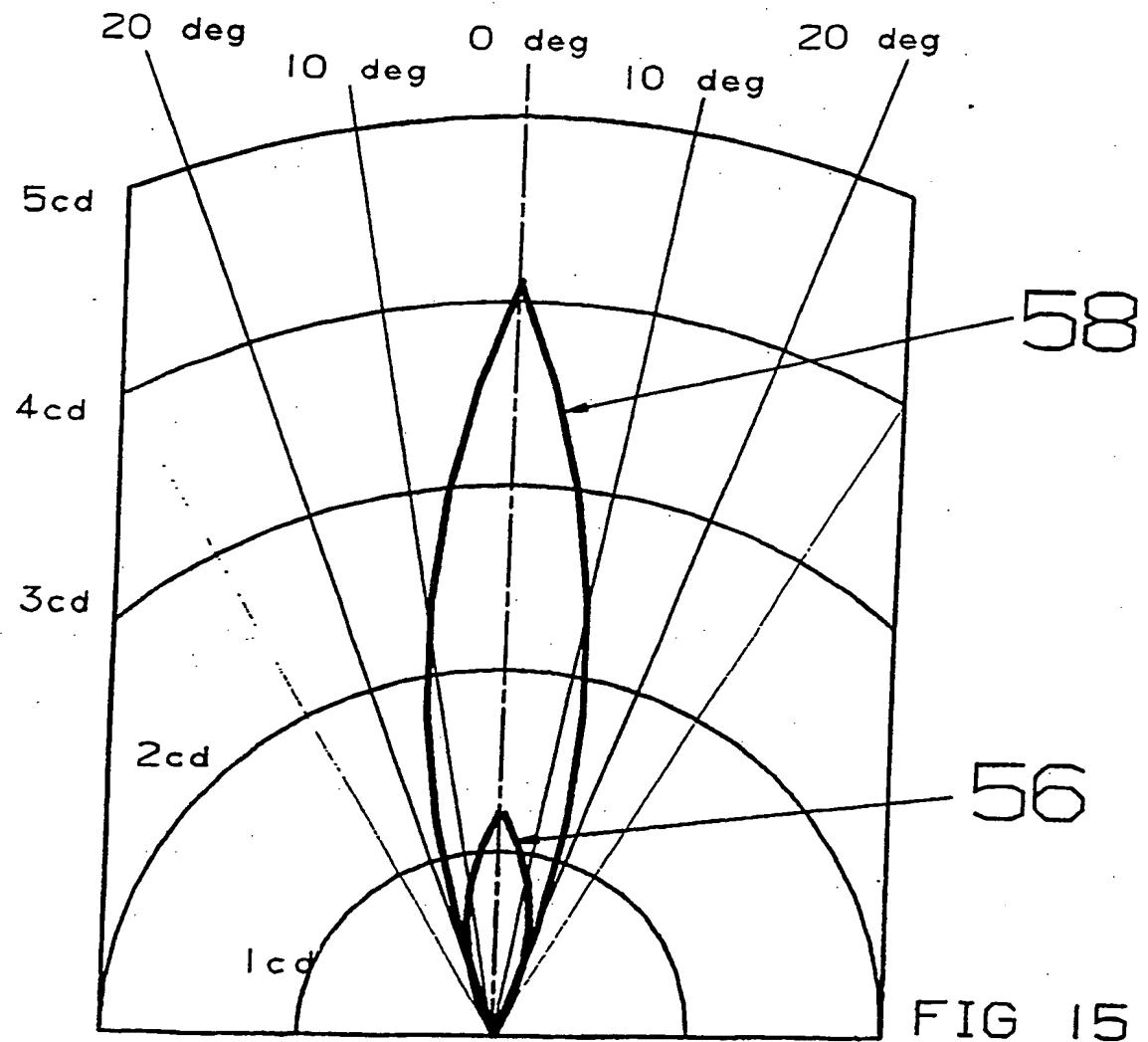
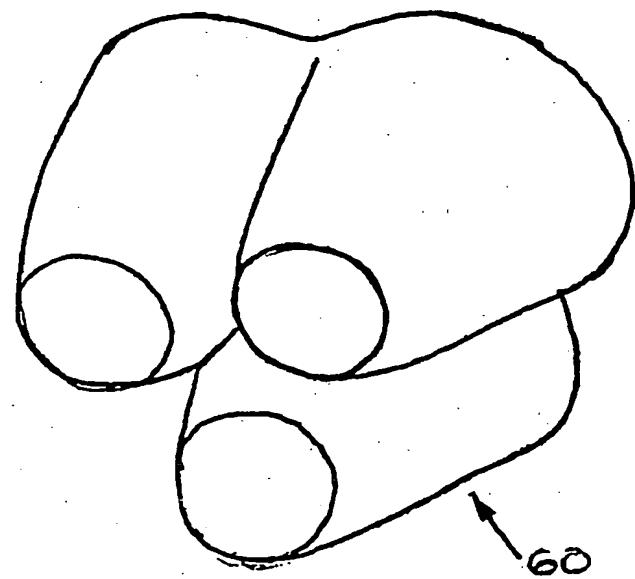
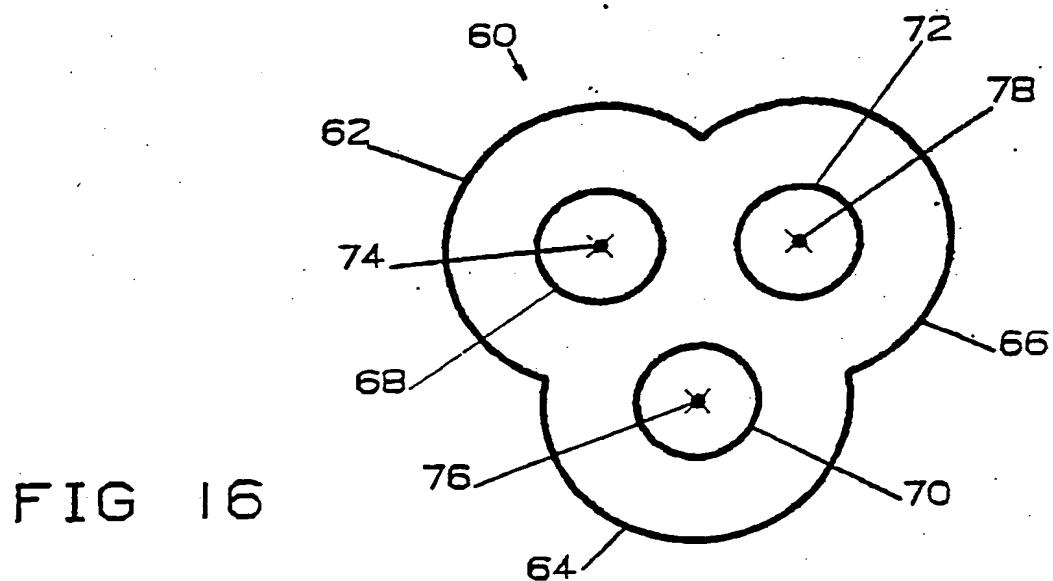


FIG 15

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A LIGHT EMITTING DIODE

This invention relates to a light emitting diode. Light emitting diodes are well known and they comprise an anode, a cathode, a light source, and a body which encapsulates the light source and which allows light from the light source to pass through the body during operation of the light emitting diode. The known light emitting diodes are such that the body is generally tubular with a light radiating end portion which is usually in the shape of a dome but which is sometimes flat. The light-emitting end portion collects approximate 30% of the light rays emitted from the light source and refracts these light rays into useful light. The remaining portion of the light emitted from the light source leaves the body through the sides of the body as non-useful light. At best, this non-useful light is just wasted which means that the light emitting diode is operating inefficiently and is providing light at less than optimum intensity. At worst, in addition to the non-useful light being wasted, it forms a nuisance and it needs to be prevented from interfering with the intended use of the light emitting diode. For example, if the light emitting diode is to be used in a blood glucose monitoring instrument, it may be necessary to surround part of the body of the light emitting diode with an optically absorbing material of low reflectivity.

such as a black plastics material or a black painted material.. The need to provide measures for preventing the non-useful light interfering with the intended use of the light emitting diode forms an extra manufacturing cost which should ideally be avoided.

It is an aim of the present invention to obviate or reduce the above mentioned problems.

Accordingly the present invention provides a body part for adding to a light emitting diode which body part is such that it is able to be mounted upon the envelope of the light emitting diode to receive lights rays which radiate from a light source in the light emitting diode and pass from the light source through the envelope at non-useful light giving angles to the optical axis of the light emitting diode, the body part causing the light rays to be totally internally reflected by the body part to form useful light emitted by the light emitting diode.

Preferably the body part receives such of the light rays as radiate from the light source in the light emitting diode and pass direct from the light source through the envelope into the body part.

The body part may also, or may alternatively, receive such of the light rays as radiate from the light source in the light emitting diode and which, in the absence of the body part, would be at least initially totally internally reflected by the envelope of the light emitting diode, the

body part being mounted upon the envelope such as to prevent total internal reflection of such light rays by the envelope of the light emitting diode, thereby to cause such light rays to pass direct from the light source through the envelope into the body part.

In order that such light rays as would otherwise be internally reflected may pass direct from the light source through the envelope into the body part, the body part is mounted upon the envelope by being cast thereto or moulded thereon, or optically cemented thereto.

The present invention also provides a light emitting diode comprising an anode, a cathode, a light source and a body which encapsulates the light source and which allows light from the light source to pass through the body during the operation of the light emitting diode: the body being such that it comprises a first portion which is for being struck by first light rays which radiate from the light source and extend at non-useful light-giving angles to the optical axis of the light emitting diode, and a second portion which is for being struck by second light rays which radiate from the light source at useful light-giving angles to the optical axis of the light emitting diode; the first portion being such that it causes the first light rays to be totally internally reflected by the first portion such as to form useful light emitted from the light emitting diode.

The light emitting diode of the present invention is thus such that the first light rays which would normally be a non-useful component of the light output of the light emitting diode are harnessed into forming part of the useful light output thereby substantially increasing the intensity of light available from a given light emitting diode and increasing its operating efficiency. In addition the invention substantially obviates the problem of non-useful light interfering with the intended use of the diode.

The first portion preferably has an inner surface at which the first light rays are totally internally reflected, which may be at least in part parabolic. The first portion may conveniently be arranged with the focus of the parabolic surface at or near the light source.

The first portion may surround the second portion, and may also extend forwardly of the second portion.

The first portion may also reflect the first light rays subsequent to their being totally internally reflected by the first portion.

The second light rays entering the second portion of the body part may also be refracted by the second portion.

The second portion of the body part may be domed, and may comprise a convex or concave lens.

The first and second portions of the body part may form a unitary body.

Alternatively the body part may be formed in two parts, the first portion being comprised in one part and the second portion in the other.

Where the body part is formed in two parts, the first and second parts may be bonded together, preferably by means of a bonding agent having a refractive index similar to the refractive indices of the material of the first and second parts, thereby to substantially obviate any total internal reflection of the first light rays within the first part.

The first and second parts may alternatively be moulded or cast together.

The first part may be the envelope of the light emitting diode, on to which the second part is mounted.

Where the light emitting diode is provided with a unitary body, the first portion may be formed in the unitary body, which may be the envelope of the light emitting diode, at least in part by machining.

The invention also enable the provision of an assembly comprising two or more light emitting diodes in which the respective first portions, or alternatively the respective first and second portions, of the two or more light emitting diodes are formed as a common structure.

The light source can be any suitable and appropriate known type of light source for light emitting diodes. Thus, for example, the light source may be a chip

containing elements such for example as gallium, aluminium and arsenic.

Embodiments of the invention will now be described solely by way of example and with reference to the accompanying drawings in which:

Figure 1 is a section through the first known light emitting diode;

Figure 2 is a section through a second known light emitting diode;

Figure 3 illustrates how light from a light source in a dense transparent medium, such as a light emitting diode in an encapsulating body is refracted or totally internally reflected;

Figure 4 illustrates how a body of a light emitting diode is struck by light rays from a light source from first, second and third zones;

Figure 5 shows a one part body configuration for causing light leaving the first zone to be internally reflected such that it forms useful light;

Figure 6 shows a body configuration which is similar to that shown in Figure 5 but which is formed in two parts instead of one part;

Figure 7 shows a one part body configuration for causing light leaving the second zone of the body to be internally reflected such that the light is able to form useful light;

Figure 8 shows a body configuration which is similar to that shown in Figure 7 but which is formed in two parts instead of one part;

Figure 9 shows how light leaving the third zone of the body can be formed into a parallel sided beam using a convex lens;

Figure 10 is similar to Figure 9 but shows how light leaving the third portion of the body can be made to increase in divergence by using a concave lens;

Figure 11 shows a one part body for a light emitting diode which combines the body configurations shown in Figures 5, 7 and 9 and which thus provides useful light from the first, second and third zones of the body;

Figure 12 is similar to Figure 11 but shows a two part body and may be regarded as being a combination of Figures 6, 8 and 9;

Figure 13 is a schematic section through a light emitting diode of the invention with a two-part body;

Figure 14 is a top plan view of the light emitting diode shown in Figure 13;

Figure 15 illustrates how the light emitting diode of Figures 13 and 14 gives an increased luminous intensity as compared with a known light emitting diode.

Referring to Figure 1, there is shown a light emitting diode 2 comprising an anode 4, a cathode 6, a light source 8 and body 10. The body 10 encapsulates the light source

8 and the body 10 also allows light from the light source 8 to pass through the body 10 during operation of the light emitting diode 2. The light emitting diode 2 has an optical axis 12. During operation of the light emitting diode 2, light from the light source 8 normally extends forwardly of the line 14 and does not extend rearwardly of the line 14.

The body 10 has a domed portion 16 and straight sides 18. The shape and position of the domed portion 16 determines the amount of light collected from the light source 8. The domed portion 16 refracts the light into a desired cone of light close to the optical axis 12. In order to obtain a wide cone of light, the domed portion 16 has to be positioned close to the light source 8. In order to achieve a narrow cone of light, the domed portion 16 has to be moved away from the light source 8.

The known light emitting diode 2 shown in Figure 1 is such that about 30% of the total available light from the light source 8 is collected by the domed portion 16 and forms useful light. The remaining light is normally regarded as stray light which is wasted. Thus, the known light emitting diode 2 operates inefficiently and it provides light at less than optimum intensity. Also, for some applications of the light emitting diode 2, for example in medical diagnostic instruments, the stray light tends to manifest itself as a background signal which needs

to be removed for optimum visibility of the light emitting diode 2. Shields or optically absorbing material often have to be employed, which increases the cost of production of the light emitting diode.

Figure 2 shows another known diode and similar parts as in Figure 1 have been given the same reference numerals for ease of comparison and understanding. In Figure 2, it will be seen that the body 10 of the light emitting diode 2 is substantially shorter than the body 10 shown in Figure 1. The light emitting diode 2 shown in Figure 2 will however operate in the same manner as the light emitting diode shown in Figure 1 except that the domed end portion 16 is very close to the light source and will therefore suffer the disadvantage of emitting light rays at wide angles to the central axis 12 of the light emitting diode.

In order to promote a full and complete understanding of the present invention, reference will now be made to Figures 3 - 10. Similar parts as in Figure 1 have again been given the same reference numerals for ease of comparison and understanding.

Figure 3 illustrates how rays of light from the light source 8 are refracted at an interface 20 between a dense transparent material 22 (e.g. the encapsulating body 10) and a less dense transparent material 24 (e.g. air). Figure 3 also illustrates how the light from the light source 8 can be totally internally reflected at the

interface 20.

As can be seen from Figure 3, rays of light from the light source 8 pass through the dense material 22 to the less dense material 24 at angles i' to lines 26 normal to the interface 20. On passing through the interface 20, the rays of light are bent at angles i . The amount of the bending depends upon the refractive index n of each of the two materials 22, 24. The amount of the bending follows the formula:

$$n \sin i = n' \sin i'$$

where n is the refractive index of the less dense material 24 and n' is the refractive index of the more dense material 22.

As can be seen from Figure 3, some rays of light from the light source 8 do not pass through the interface 20 but are reflected back into the more dense material 22. This is caused by what is known as total internal reflection. The total internal reflection follows the formula:

$$\sin i_c = n'/n$$

where i_c is the critical angle.

The totally internally reflected light obeys the rule that the incident angle equals the reflected angle, and all light rays from within the more dense material 22 striking the interface 20 at angles greater than the critical angle will be reflected.

Figure 4 uses the information shown in Figure 3 to

illustrate how the known light emitting diode 2 shown in Figure 1 emits light rays from the light source 8 over three zones which are shown in Figure 4 as zone 1, zone 2 and zone 3.

The light rays in zone 3 are those light rays which strike the domed portion 16 and are usefully refracted to a cone of light close to the optical axis 12 of the body 10.

The light rays in zone 2 are those rays of light which strike the inner surface of the body 10 at such an angle as to obey the rule of total internal reflection. These light rays therefore bounce within the body 10 until they eventually radiate out as shown in generally useless directions.

The light rays in zone 1 are those light rays which strike the straight sides 18 of the body 10 and, after some refraction, radiate out at large angles to the optical axis 12 and are therefore useless. The light rays in zones 1 and 2 may also be a nuisance in some uses of the light emitting diode 2 and these light rays may need to be eliminated, for example by the use of shields or by use of an optically absorbing material placed around the body 10.

Referring now to Figures 5 and 6, Figure 6 shows how a part 38 may be mounted upon the original body part 10 of the light emitting diode 2 to receive light rays which radiate from the light source 8 and leave the body part 10

within zone 1, at non-useful light giving angles to the optical axis 12. Such light rays enter part 38, strike internal surface 40 and are totally internally reflected at surface 40 to exit part 38 forwardly, such as to become useful light emitted from the light emitting diode 2. The configuration of surface 40 of part 38 must be such as to ensure that as much as possible of the light in zone 1 which impinges upon it is totally internally reflected and upon reflection is forwardly directed. By making surface 40 parabolic or part parabolic, with its focus at or near the source 8 of the light emitting diode 2, this requirement may be conveniently met.

The construction shown in Figure 6 is the more appropriate where standard encapsulated light emitting diodes are to be fitted with a separately manufactured part 38 to increase their useful light output.

Figure 5 shows how the body part 10 may be formed integrally with the part 38 at the time of manufacture of the light emitting diode 2, to fulfil the same criteria.

In both cases the domed portion 16 of the light emitting diode receives and transmits forwardly light rays radiating at useful light-giving angles to the optical axis 12 of the light emitting diode.

Figures 7 and 8 show configurations which utilise the non-useful light rays which are emitted in zone 2 as shown in Figure 4.

Referring to Figure 8, a separate body part 32 is mounted upon the body part 10 of an existing light emitting diode 2, in such a manner as to ensure that light rays in zone 2 of Figure 4, which would otherwise be totally internally reflected within body part 10, pass directly into part 32 and are totally internally reflected at surface 34 to exit part 32 forwardly and thus become useful light emitted from the light emitting diode. Surface 34 is configured such as to ensure total internal reflection forwardly in part 32 of light entering part 32 from zone 2 of light emitting diode 2, and may, as in the previous instance, be parabolic or part parabolic.

To obviate total internal reflection within body 10, body part 32 is mounted upon the portion of body 10 in the region where such reflection would occur in such a manner as to remove the body/air interface. This may be achieved by optically bonding the two parts with a bonding agent 36 having substantially the same refractive index as each of the separate parts 10 and 32, or by casting or moulding part 32 on to body part 10.

Figure 7 shows how the body part 10 may be formed integrally with the part 32 to similarly transform into useful light, light rays falling within zone 2 of Figure 4, although it will be appreciated that where, as here, body 10 and part 32 are formed integrally there will be no total internal reflection within the body 10, and light rays in

zone 2 will radiate direct from source 8 to surface 34.

In both Figure 7 and Figure 8 constructions the domed portion 16 receives and forwardly directs light rays radiating at useful light-giving angles to the optical axis 12 of the light emitting diode.

Figure 9 shows how a convex aspheric or spherical lens 28 can be placed at the end of the body 10 to provide a reduced beam cone angle. Figure 10 shows the use of a concave aspheric or spherical lens 30 for the purpose of increasing the beam cone angle. The lenses 28, 30 can optionally be provided to act on light rays from the domed portion 16. These light rays are useful light rays and they are not light rays which are intended to be improved on by the present invention. In the present invention, any alterations to the light rays leaving the domed portion 16 are simply to change the beam width and there will be no increase in the total luminous flux available from these light rays since the same number of light rays are collected and deflected.

Referring to Figures 11 and 12, light emitting diodes with one part and two part bodies are shown, which receive non-useful light emitted by the light emitting diodes and form it into forwardly directed useful light, substantially parallel to the optical axis of the light emitting diode.

Figure 11 shows a one part body 10 receiving zone 1 light on surface 40 of section 38, zone 2 light on surface

34 of section 32, and zone 3 light upon section 16, all from light emitting diode source 8. Surfaces 34 and 40 totally internally reflect light striking them and direct it forwardly through annular end face 52, which may be shaped, for example domed, if it is desired to converge or diverge the light rays emergent from face 52.

It will be appreciated that the one part body Figure 11 is a combination of the one part bodies of Figures 5 and 7.

Figure 12 is a light emitting diode in accordance with the invention having a two part body, where a separately manufactured part 50 is, at 36, optically bonded to, or moulded or cast upon, the body 10 of a standard encapsulated light emitting diode to increase its useful light output. The part 50 also incorporates portions 32 and 38, respectively having surfaces 34 and 40 at which non-useful first light rays emergent from the body 10 of the light emitting diode are totally internally reflected to form useful light. Useful, second, light rays are directed out of body 10 and through face 16 of body 50 substantially parallel to the optical axis 12 of the light emitting diode.

It will be appreciated that the light emitting diode in accordance with the invention shown in Figure 12 is a combination of the embodiments of Figure 6 and Figure 8 in combination with a standard encapsulated light emitting

diode.

Figures 13 and 14 show a light emitting diode 2 which is like that shown in Figure 12 and which can be produced to have the actual illustrated measurements. In Figure 13, the added part 50 is bonded by optical cement to the body 10 of a known light emitting diode 2 which is manufactured by Toshiba and which is known as a Toshiba TLOA156P.

The referenced dimensions A to P in Figures 13 and 14 have the following values, in millimetres:

A	13.75	G	9.50	M	3.40
B	10.78	H	9.18	N	2.59
C	8.00	J	8.37	P	1.42
D	0.95	K	7.28		
F	6.10	L	3.88		

Surface 54 of part 50, the surface receiving the first (ie zone 1 and zone 2) light rays, is the surface of revolution of a parabola of focal length 1.00mm with its focal point at the light source 8 in body of the Toshiba TLOA156P light emitting diode upon which part 50 is mounted.

Such a light emitting diode has at a specified electrical input a luminous intensity of 1.2 candela along its optical axis 12, reducing to 0.8 candela around the perimeter of the base of a cone of 20° apex angle. The added part 50 increases the luminous intensity of the light emitting diode 2 to 4.2 candela reducing to

2.4 candela around the perimeter of the cone base. These respective luminous intensity plots are shown as 56 and 58 in Figure 15. The added part 50 approximately trebles the useful luminous intensity available from the known Toshiba light emitting diode 2.

It is to be appreciated that the embodiments of the invention described above with reference to the accompanying drawings have been given by way of example only and that modifications may be effected. Thus, referring to Figures 11 and 12, the shape of the body 10 may be varied whilst still having the required light directing portions 16, 32 and 38. The body of the light emitting diode 2 may be made of polymethymethacrylate or any other material used for making the bodies of known light emitting diodes. The polymethymethacrylate preferably has a critical angle of 42 degrees 15 minutes. The light emitting diode of the present invention may generally be used in all applications where known light emitting diodes are used.

If desired, a plurality of body parts comprising the first portion 38 and optionally the second portion 32 may be moulded together in the form of a matrix of a required shape. The matrix may then be used in an intended use, for example in the automobile industry, with known light emitting diodes, for example as shown in Figures 1 and 2, being inserted into the moulded matrix.

In a specific variant the matrix may comprise a body able to receive three encapsulated light emitting diodes, the body having three respective part-parabolic surfaces, each able to receive first light rays from its respective light emitting diode and to direct it forwardly, in the same direction as the useful second light rays from that diode. By arranging for the diodes to be differing types with different colour characteristics, and by powering the different diodes to operate at appropriate parts of their characteristics, the combined light output may be arranged to approximate to white light, which individual light emitting diodes are unable to produce.

The plan view of such a matrix 60 is shown in Figure 16 of the drawings, with three parabolic surfaces 62, 64, 66 related to three discrete light emitting diodes 68, 70 and 72 containing light sources 74, 76 and 78. A perspective view of the matrix 60 is shown in Figure 17.

It will be appreciated that the light directing bodies in accordance with the invention may be used as light collecting elements able to efficiently receive light incoming along substantially parallel paths and focus it to a point. For example in a part such as is shown in Figure 11, such light would enter through faces 16 and 52 and be directed to a focus at the point at which source 8 lies in Figure 11. In such an application a light detector could for example be positioned at the focal point.

In Figures 1, 2 and 4 to 13 of the drawings cross hatchings have been omitted from sections to show more clearly the passage of the light ray therethrough.

CLAIMS

1. A body part for adding to a light emitting diode which body part is such that it is able to be mounted upon the body of the light emitting diode to receive rays which radiate from a light source in the light emitting diode and pass from the light source through the body at non-useful light giving angles to the optical axis of the light emitting diode, the body part causing the light rays to be totally internally reflected by the body part to form useful light.
2. A body part according to Claim 1 which receives such of the light rays as radiate from the light source in the light emitting diode and pass direct from the light source through the body into the body part.
3. A body part according to Claim 1 or Claim 2 which receives such of the light rays as radiate from the light source in the light emitting diode and which, in the absence of the body part, would be at least initially totally internally reflected by the body of the light emitting diode, the body part being mounted upon the body such as to prevent total internal reflection of those light rays by the body of the light emitting diode, thereby to cause those light rays to pass direct from the light source through the envelope into the body part.

4. A body part as claimed in Claim 3 which is mounted upon the body of the light emitting diode by being cast thereto or moulded thereupon.
5. A body part as claimed in Claim 3 which is mounted upon the body of the light emitting diode by being optically cemented thereto.
6. A body part according to Claim 1 and substantially as herein described with reference to any one of Figures 6, 8, 12 or 13 and 14 of the accompanying drawings.
7. A light emitting diode when provided with a body part according to any one of the preceding claims.
8. A light emitting diode comprising an anode, a cathode a light source and a body which encapsulates the light source and which allows light from the light source to pass through the body during operation of the light emitting diode: the body being such that it comprises a first portion which is for being struck by first light rays which radiate from the light source and extend at non-useful light-giving angles to the optical axis of the light emitting diode, and a second portion which is for being struck by second light rays which radiate from the light source at useful light-giving angles to the optical axis of

the light emitting diode; the first portion being such that it causes the first light rays to be totally internally reflected such as to form useful light emitted from the light emitting diode.

9. A light emitting diode according to Claim 8 in which the first portion has an inner surface at which the first light rays are totally internally reflected.

10. A light emitting diode according to Claim 9 in which the inner surface is at least in part parabolic.

11. A light emitting diode according to Claim 10 in which the first portion is arranged with the focus of the parabolic surface at or near the light surface.

12. A light emitting diode in accordance with any one of Claims 8 to 11 in which the first portion surrounds the second portion.

13. A light emitting diode in accordance with Claim 12 in which the first portion extends forwardly of the second portion.

14. A light emitting diode in accordance with any one of Claims 8 to 13 in which first light rays totally internally

reflected by the first portion are subsequently refracted by the first portion.

15. A light emitting diode in accordance with any one of Claims 8 to 14 in which second light rays entering the second portion are refracted by the second portion.

16. A light emitting diode in accordance with any one of Claims 8 to 15 in which the second portion is domed.

17. A light emitting diode in accordance with any one of Claims 8 to 15 in which the second portion comprises a concave or a convex lens.

18. A light emitting diode in accordance with any one of Claims 8 to 17 which the first and second portions form a unitary body.

19. A light emitting diode in accordance with any one of Claims 8 to 17 which the body is formed in two parts, the first portion being in one part and the second portion in the other.

20. A light emitting diode in accordance with Claim 19 in which the second part is bonded to the first part.

21. A light emitting diode in accordance with Claim 20 in which the first and second parts are moulded or cast together.
22. A light emitting diode in accordance with Claim 20 in which the first and second parts are bonded together with a bonding agent having a refractive index similar to the refractive index of the material of the first and second parts.
23. A light emitting diode in accordance with Claim 18 in which the unitary body is formed at least in part by machining.
24. An assembly comprising two or more light emitting diodes as claimed in any of Claims 8 to 23 in which the respective first portions of each light emitting diode are formed as a single structure.
25. An assembly comprising two or more light emitting diodes as claimed in any one of Claims 8 to 23 in which the respective first and second portions of each light emitting diode are formed as a single structure.
26. A light emitting diode in accordance with Claim 8 and substantially as herein described with reference to any one

of Figures 5, 6, 7, 8, 11, 12 or 13 and 14.

Relevant Technical Fields

- (i) UK CI (Ed.M) H1K (KEE, KQAME)
 (ii) Int CI (Ed.5) F21V H01L

Search Examiner
S J MORGAN

Date of completion of Search
7 NOVEMBER 1994

Databases (see below)

- (i) UK Patent Office collections of GB, EP, WO and US patent specifications.

- (ii) ONLINE DATABASE: WPI

Documents considered relevant following a search in respect of Claims :-
1-5, 7

Categories of documents

- | | | | |
|----|---|----|---|
| X: | Document indicating lack of novelty or of inventive step. | P: | Document published on or after the declared priority date but before the filing date of the present application. |
| Y: | Document indicating lack of inventive step if combined with one or more other documents of the same category. | E: | Patent document published on or after, but with priority date earlier than, the filing date of the present application. |
| A: | Document indicating technological background and/or state of the art. | &: | Member of the same patent family; corresponding document. |

Category	Identity of document and relevant passages		Relevant to claim(s)
X	EP 0397911 A1	(SIEMENS) see Figure 5 and lines 44-50, column 3	1,2,7
X	US 5122943	(PUGH) see lines 21-47, column 3, and Figure 1	1,2,7
X	US 5173810	(AISENS) see whole document	1,7

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).